

# REPORT

January 2019

Project Id: COV2018-4

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## 2018 Annual Catalytic Oxidizer Performance Test

*Prepared for*



**Covidien LP**  
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North Haven, CT 06473

*Prepared by*



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# TEST REPORT

2018 Catalytic Oxidizer Performance Test

Report Certification

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I certify that to the best of my knowledge:

- The information provided in this document is true, accurate, and complete.
- Any deviations from published test methods are identified and described in detail.
- Testing will be conducted according to the approved protocol.
- All deviations, method modifications, or sampling and analytical anomalies will be summarized in the appropriate report narrative(s).

*Evan Bali*

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Evan Bali, QSTI  
Project Manager

January 30, 2019  
Date

# TEST REPORT

## 2018 Catalytic Oxidizer Performance Test

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## **1 INTRODUCTION**

### **1.1 Overview**

Canomara LLC was contracted by Covidien LP to conduct the 2018 annual performance test on the catalytic oxidizer used to control ethylene oxide (ETO) emissions from a medical product sterilizer at the North Haven, CT facility. The sterilization process includes two sterilizer chambers vented to a shared control system designed and manufactured by LESNI. The sterilization process is regulated by 40 CFR 63, Subpart O (i.e., the National Emission Standards for Hazardous Air Pollutants for Ethylene Oxide Sterilization Facilities or the MACT rule) and Connecticut Department of Energy and Environmental Protection (DEEP) permits 135-0143 and 135-0144.

As per 40 CFR 63 Subpart O, amended on November 2, 2001, Covidien LP elects to test the catalytic oxidizer annually to determine ethylene oxide destruction efficiency. The specification for the test is contained in 40 CFR 63.363 (b)(4)(i). Subpart O initially required catalyst replacement based upon the manufacturer's recommendation (typically every 5 years); however, the rule was changed and now permits a facility to use the same catalyst until a performance test indicates that the ETO removal efficiency is less than the mandated 99%. If the efficiency is less than 99%, the facility must restore the catalyst as soon as practicable but no later than 180 days after conducting the performance test.

Testing was conducted in accordance with EPA Methods 1, 2, and 18. Gas samples were collected from the oxidizer inlet and outlet in Tedlar bags simultaneously and the bags were analyzed on the following day by gas chromatography. Three 1-hour inlet/outlet sample sets were collected and analyzed. During sampling, the process was operated at a worst-case condition, which included unloading both sterilizers into primary aeration.

The performance test occurred on January 7, 2019 and was observed by Mr. Timothy Marsh of CT DEEP. Testing was originally scheduled for December 3, 2018; however, the sterilizer process wasn't in operation which delayed testing until January 7.

## **1.2 Contact Information**

The test was conducted by Evan Bali and Ed Gutfran and supervised by James Canora. Ms. Kimberly Zuraw, Sr. EHS Specialist, with Covidien served as test coordinator. Contact information is as follows:

Kimberly Zuraw  
Covidien LP  
195 McDermott Road  
North Haven, CT 06473  
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[kimberly.zuraw@medtronics.com](mailto:kimberly.zuraw@medtronics.com)

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## **1.3 Report Organization**

Section 2.0 of this report contains a summary of results. Section 3.0 describes the process operations. Section 4.0 describes the sampling and analytical methods and Section 5.0 describes the quality assurance procedures. Complete data are included in the appendices.

## 2 RESULTS

The tests showed that ethylene oxide destruction efficiency was greater than 99.44%. The ethylene oxide concentration on the oxidizer outlet was below the Method 18 detection limit on all three tests. Results are summarized in Table 2-1 and complete data sets are contained in the appendices.

**Table 2-1: 2017 Catalytic Oxidizer Performance Test Summary**

Test No.	1	2	3	Average	DEEP Permit Limit	Subpart O Permit Limit
<b>Continuous Process Monitoring Data</b>						
Oxidizer Exit Temperature (°C)	158.3	157.6	157.3	157.7		
<b>Emission Test Data</b>						
Oxidizer Inlet Gas Flow Rate (scfm)	6310	6206	6294	6270		
Oxidizer Outlet Gas Flow Rate (scfm) <sup>1</sup>	6310	6206	6294	6270		
Oxidizer Inlet ETO Concentration (ppm-wet)	47.02	36.36	28.02	37.13		
Oxidizer Outlet ETO Concentration (ppm-wet)	<0.20	<0.20	<0.20	<0.20	1.0	1
Oxidizer Inlet ETO Emission Rate (lb/hour) <sup>2</sup>	2.04	1.55	1.21	1.60		
Oxidizer Outlet ETO Emission Rate (lb/hour)	<0.009	<0.009	<0.009	<0.009	<0.059	
Destruction Efficiency (%) <sup>3</sup>	>99.57%	>99.45%	>99.29%	>99.44%		99%

1. Outlet gas flow rate was assumed to be the same as the inlet.

2. lb/hour = ppm-wet x scfm x MW x 15.58 x 10<sup>-8</sup>

MW = molecular weight of ethylene oxide (44.05)

3. Destruction Efficiency = (ER<sub>inlet</sub> - ER<sub>outlet</sub>)/ER<sub>inlet</sub> x 100

ER = emission rate (lb/hour)

### **3 PROCESS DESCRIPTION**

Covidien produces a variety of medical and surgical appliances and has recently installed two medical appliance sterilizers. The sterilizers use pure ETO sterilant gas. Emissions from the sterilizer chamber vents and primary aeration vents are controlled with a LENS catalytic abator system. The sterilization process also includes two secondary aeration rooms and these rooms are vented directly to atmosphere as the emission concentration is less than 1 ppm.

#### **3.1 Sterilization and Aeration Process Description**

Product to be sterilized is waiting in the staging/preconditioning room (PCR) where it gets exposed for approximately 6 hours to temperatures between 67° - 115° F and humidity of 40% – 70% depending on specific product's needs.

There are two sterilizer chambers, each equipped for 6 pallet loads. Pallets dimensions do not exceed the following dimensions: width 42" x height 71" x length 48". The system was initially designed for four chambers; however, only two were built. Packaged medical products are loaded into the chambers, conditioned to specified temperature and humidity and sterilized with a maximum 50 pound charge of ETO. The sterilization cycle times are different for different products with a range of 9 to 22 hours.

At the end of the sterilization cycle, the chamber gas is evacuated to the LESNI and product is conveyed to the primary aeration rooms. The evacuation process includes multiple pumped evacuations followed by nitrogen charges and this process is referred to as washes. The number of washes is variable depending on the product type, but all evacuations are conducted with the same vacuum pumps exhausted to the balancer tank.

Each sterilizer chamber has a dedicated primary aeration room and each room is equipped with multiple gas collection intakes near the floor. The primary aeration time is typically 12 hours; however, the ETO concentration in the room must be less than 1.5 ppm to end the cycle. After primary aeration, product pallets are moved with a fork-lift to either of the two secondary aeration rooms. One room is dedicated to suture products and the other room is dedicated to polymer products. Both secondary rooms are exhausted with a shared pair of ID fans located on the roof. The two fans are operated in parallel and provide a redundant exhaust fan in the event of failure. The final exhaust to atmosphere is through a 36-inch diameter stack.

### 3.2 LESNI Abator System

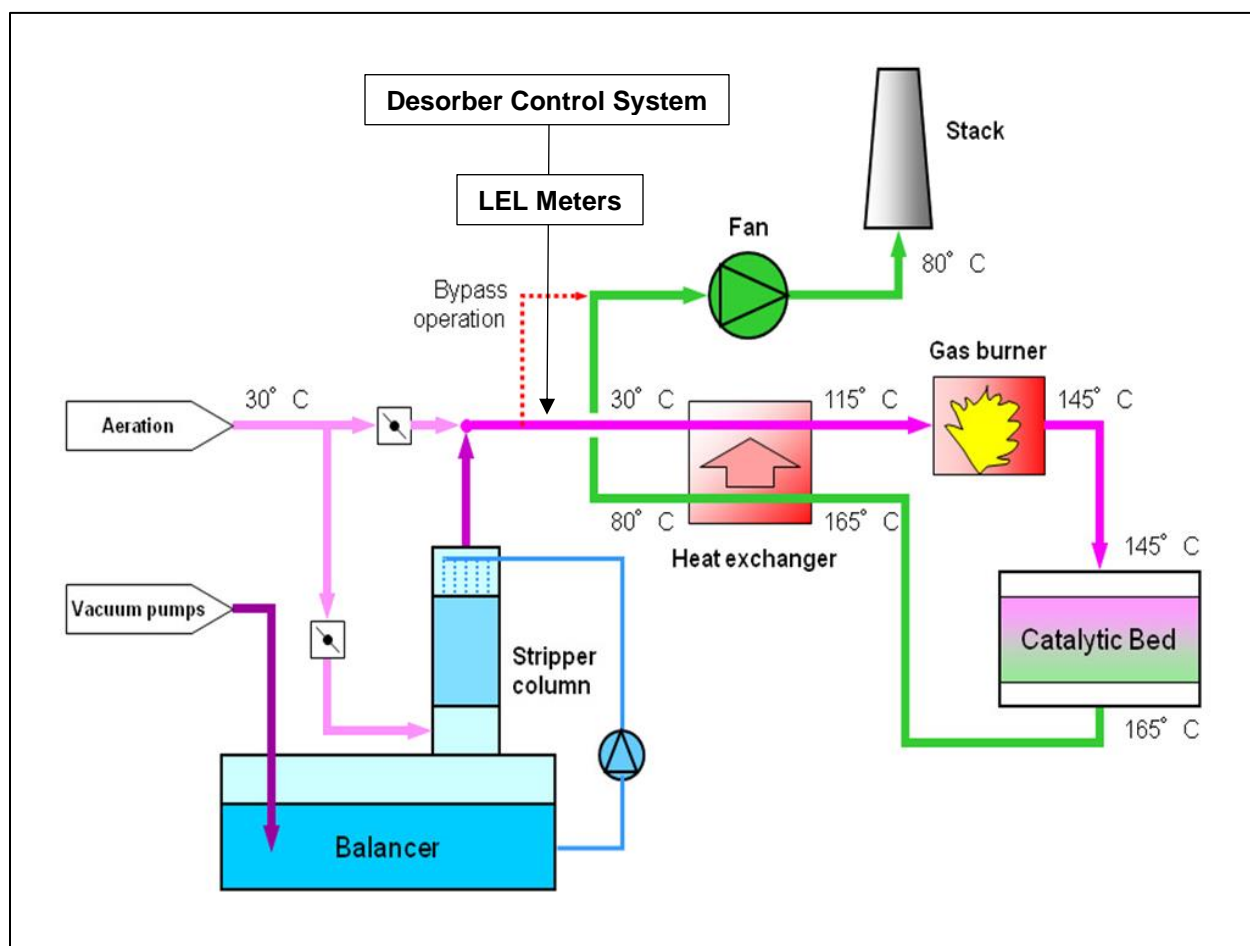
The LESNI Catalytic abator system is designed to control ETO emissions from chamber venting and primary aeration using catalytic oxidation preceded by a balancer that buffers high concentration chamber vent emissions. The LESNI converts ETO to CO<sub>2</sub> and H<sub>2</sub>O without chemical additives (sulfuric acid) and without producing ethylene glycol waste. The system is designed to meet the 99% reduction and 1.0 ppm MACT limits. A simplified process schematic is presented in Figure 3-1.

The LESNI receives exhaust gas from the primary aeration rooms through a common duct and from the chamber vents via the balancer. The exhaust fan is located after the oxidizer and this fan maintains a negative pressure on the aeration rooms, the balancer and all associated equipment and ductwork. Aeration rooms are exhausted through floor level intakes and these intakes are connected below the roof to a common 24-inch duct. On the roof, the common aeration room duct is split to two booster fans that are engineered to maintain a negative pressure on the aeration room in the event of a failure with the LESNI fan. The ETO concentration in the primary aeration exhaust is low (typically less than 100 ppm).

The sterilizer chamber evacuations generate high concentration ETO exhaust streams and the LESNI is designed to buffer these high concentrations with an aqueous absorber/desorber identified as the balancer, so that the oxidizer is never subjected to un-buffered gas. The primary functional components of the chamber exhaust system are (1) water sealed vacuum pumps, (2) sparger tubes, (3) balancer tank, (4) stripper column, and (5) desorber control system. These components are shown in Figure 3-1. Each chamber has a single dedicated vacuum pump rated for 250 scfm. Each vacuum pump is directly piped to a sparger tube on the balancer tank that exits below the tank water level so that the incoming gas is bubbled through the water to absorb ETO. The vacuum pumps have water seals and the seal is formed from balancer tank water pumped to and from the vacuum pumps. The balancer tank contains 15,000 liters of water which can absorb up to 450 pounds of ETO. The stripper column physically rests on the top of the balancer tank and water is continuously pumped from the tank to spray nozzles located on the top of the stripper column. The sprayed water falls through the column back into the tank through a counter current air flow that enters the bottom of the column. The counter current air flow is a slipstream of the primary aeration exhaust, so that in effect, the balancer absorbs high concentration chamber vent ETO emissions in water and then uses the low concentration primary

aeration exhaust air to strip ETO from the water. The balancer tank water temperature is also monitored and controlled to a range of 5 °C to 28 °C.

**Figure 3-1**  
**Process Schematic**



ETO desorption from the balancer tank is controlled to limit the rate of ETO entering the catalytic oxidizer. This control is conducted automatically with three procedures including the water spray rate at the top of the stripper column, counter current air flow rate through the column (this air flow is a slipstream of the primary aeration exhaust) and a pair of redundant LEL meters located 30 inches downstream of the stripper column return pipe. The control setting at Covidien is 2.5% of the LEL which is equivalent to 750 ppm of ETO. When the LEL is low, the desorption rate is maximized with low water spray rate on to the top of the column and high counter current air flow rate. When the LEL increases as chamber venting occurs, the water spray rate is increased, and counter current air flow rate is reduced with a controlled damper to maintain LEL below the set point. The position of this stripper air control damper is a measured and recorded process parameter.

The balancer stripper exit re-combines with the primary aeration exhaust and the combined gas is preheated with a shell and tube type heat exchanger and then enters the gas fired heater. The heat exchanger and gas fired heater raise the temperature to the required catalyst inlet temperature which is 145 °C. The preheated gas enters the catalytic oxidizer and three parallel beds oxidize ETO. The catalyst bed exit gas temperature increases across the beds and temperature is monitored at the catalyst bed inlet and at the outlets of all three beds. Recorded temperatures include the catalyst inlet, catalyst bed outlets, and the average catalyst bed outlet. The average catalyst bed outlet temperature is set to a minimum of 150 °C. The exhaust fan is installed after the catalytic abator, and this single fan provides the necessary suction for extracting the process air through the system maintaining a negative pressure on the exhaust process.

### **3.3 LESNI Process Monitoring**

The sterilizer chamber and LESNI are monitored and controlled with a computer-based control system operated in a state of the art control room. Temperature, humidity, pressure and ETO charge weights are primary parameters monitored on each sterilizer chamber. The LESNI abator is monitored extensively and the principal parameters used for control are LEL sensors on the balancer and the combined catalyst bed outlet temperature. The oxidizer temperature monitoring complies with 63.363(b)(3) and 63.364(c).

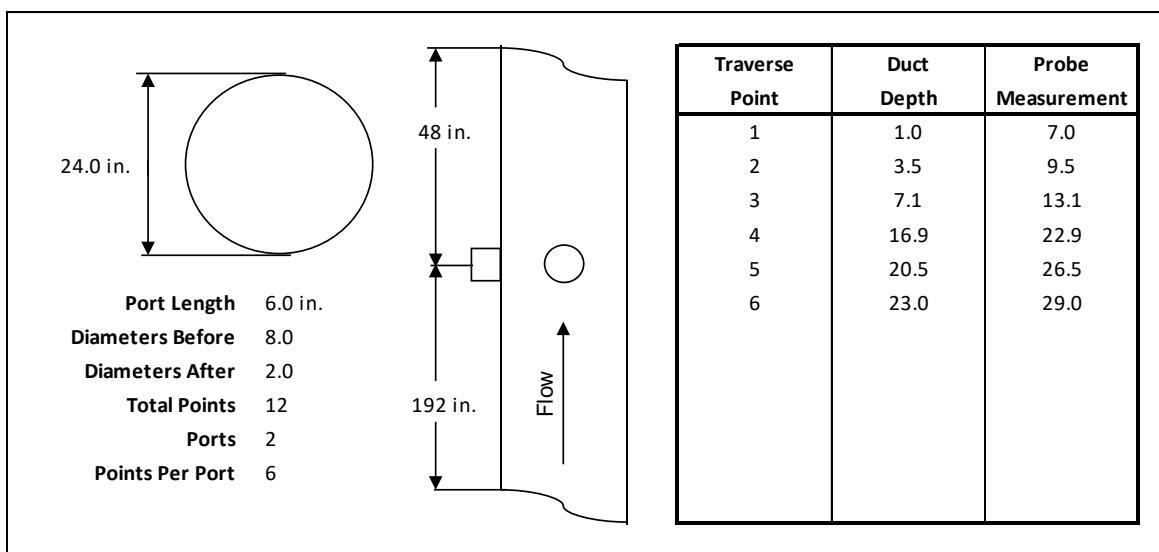
## 4 SAMPLING & ANALYTICAL PROCEDURES

ETO emissions were measured concurrently at the oxidizer inlet and outlet and destruction efficiency was demonstrated on a mass basis. The tables and paragraphs below describe the test methods and detailed method descriptions are contained in Appendix A.

**Table 4-1: Reference Methods**

Method	Description
EPA 1	Sample and Velocity Traverses for Stationary Sources
EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA 18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography

**Figure 4-2  
Inlet Traverse Points**



## **5 QUALITY ASSURANCE**

CM's quality assurance program is designed so that work is performed by competent, experienced individuals using properly calibrated equipment, approved procedures for sample collection, recovery, and analysis and proper documentation. This ensures the integrity of data collected, processed, and reported on each project.

### **5.1 Sampling and Flow Equipment**

Sampling and measurement equipment, including continuous analyzers, recorders, pitot tubes, dry-gas meters, orifice meters, thermocouples, probes, nozzles, and any other pertinent apparatus, is uniquely identified, undergoes preventive maintenance, and is calibrated before and after each field effort, following written procedures and acceptance criteria. Calibrations are performed with standards traceable to the National Institute for Science and Technology (NIST) when required. Standards used include wet-test meters, standard pitot tubes, and NIST Standard Reference Materials. Records of all calibration data are maintained in CM files.

### **5.2 EPA Method 18**

Sampling and analytical quality control for EPA Method 18 include sampling flow rate calibration, leak checking before each test, bag wall loss recovery study, triplicate analyses, pre-analysis multi-level calibration and a post-analysis single-level calibration. In addition, any dilutions made on samples or calibration gases will be verified by the testing firm. The Teflon tube used for sampling transfer lines will be new, steel probes will be new, and dedicated inlet/outlet equipment will be used. The sampling trains will be leak checked before each test run using a flow leak check procedure. The sampling probe inlet is sealed and the sampling train is evacuated to a vacuum greater than 5 inches of Hg. An acceptable leak rate is no observed flow over a 30 second period.

The calibration precision is measured during the initial calibration by analyzing each calibration gas three times and each of the three runs was within 5% of the mean. Bag wall loss is determined by spiking one of the samples with a known amount of ETO and then re-analyzing the spiked sample. The spike recovery is calculated in accordance with EPA Method 18 and recovery must be  $\pm 30\%$ .

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# **APPENDIX A**

## **Gas Flow Rate Data**

Covidien - North Haven, CT  
Oxidizer Inlet (24-inch horizontal pipe)

EPA 1, 2, 18  
Summary Table

Canomara LLC  
Source Testing Services

Item	Description	Run 1	Run 2	Run 3	Average	Compliance
Date	Test Date	1/7/2019	1/7/2019	1/7/2019		
Start	Run Start Time	8:50	10:00	11:08		
Finish	Run Finish Time	9:50	11:00	12:08		
$\theta$	Net Run Time, minutes	60.0	60.0	60.0	60.0	
$N_{tp}$	Net Traversing Points	12	12	12	12	
$C_p$	Pitot Tube Coefficient	0.840	0.840	0.840	0.840	
$P_{Br}$	Barometric Pressure, inches of Mercury	30.52	30.52	30.52	30.52	
% $H_2O$	Moisture Content of Stack Gas, %	1.2	1.2	1.2	1.2	
$M_{fd}$	Dry Mole Fraction	0.988	0.988	0.988	0.988	
% $CO_2$	Carbon Dioxide, %	0.00	0.00	0.00		
% $O_2$	Oxygen, %	20.90	20.90	20.90	20.90	
% $CO + N_2$	Carbon Monoxide & Nitrogen, %	79.1	79.1	79.1	79.1	
$M_d$	Dry Molecular Weight, lb/lb-Mole	28.84	28.84	28.84	28.84	
$M_s$	Wet Molecular Weight, lb/lb-Mole	28.71	28.71	28.71	28.71	
$P_g$	Flue Gas Static Pressure, inches of $H_2O$	-2.20	-2.20	-2.20	-2.20	
$P_s$	Absolute Flue Gas Pressure, inches of Mercury	30.36	30.36	30.36	30.36	
$T_s$	Average Stack Gas Temperature, °F	55.0	54.0	56.4	55.1	
$\Delta P_{avg}$	Average Velocity Head, inches of $H_2O$	0.340	0.328	0.339	0.336	
$A_s$	Stack Crosssectional Area, square feet	3.1	3.1	3.1	3.1	
<b>FLOW</b>						
$V_s$	Average Stack Gas Velocity, fps	32.2	31.6	32.2	32.0	
$V_s$ (fpm)	Average Stack Gas Velocity, fpm	1,931	1,895	1,931	1,919	
$Q_{aw}$	Actual Wet Volumetric Flue Gas Flow Rate, acfm	6,066	5,954	6,067	6,029	
$Q_{sw}$	Standard Wet Volumetric Flue Gas Flow Rate, scfm	6,310	6,206	6,294	6,270	
$Q_{sw}$ (scfh)	Standard Wet Volumetric Flue Gas Flow Rate, scfh	378,603	372,376	377,643	376,207	
$Q_{sd}$	Standard Dry Volumetric Flow Rate, dscfm	6,235	6,132	6,219	6,195	
$Q_{sd}$ (dscfh)	Standard Dry Volumetric Flow Rate, dscfh	374,086	367,932	373,140	371,719	
<b>ETHYLENE OXIDE</b>						
EO ppm-inlet	Ethylene Oxide Concentration, ppm-wet	47.02	36.36	28.02	37.13	
EO lb/hour-inlet	Ethylene Oxide Emission Rate, lb/hour	2.04	1.55	1.21	1.60	

## Flow Data

Project			Source		Pitot Tube			Date	Operators
Id	Client	Facility	Id	Location	Leak Check	Id	Cp		
Low 2010-2	Low	Skidder	OK	Inlet	+ ✓	4-1	0.04	1-7-19	ES/EL

[illegible][illegible][illegible][illegible]

**Notes:**

## Non-Isokinetic Source Sampling Data Sheet

Project			Source	
ID	Client	Facility	ID	Location
0002488	COV	Sterilizer	04	101st

Dry Gas Meter		Barometric Pressure (in Hg)	Date	Operators
ID	Δ H @ Y			
U2054		30.52	1-7-19	CD/26

Run	Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Time				Initial Leak Check				Final Leak Check			
				Temperature (°F)				in Hg		cfm		in Hg		cfm	
				Impinger	DGM In	DGM Out	Vacuum (in Hg)	Impinger	DGM In	DGM Out	Vacuum (in Hg)				
2	0	T	0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	10		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	20		0.1	51	50	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	30		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	40		0.1	51	50	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	50		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	60		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000

Run	Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Time				Initial Leak Check				Final Leak Check			
				Temperature (°F)				in Hg		cfm		in Hg		cfm	
				Impinger	DGM In	DGM Out	Vacuum (in Hg)	Impinger	DGM In	DGM Out	Vacuum (in Hg)				
2	0	T	0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	10		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	20		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	30		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	40		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	50		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	60		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000

Run	Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Time				Initial Leak Check				Final Leak Check			
				Temperature (°F)				in Hg		cfm		in Hg		cfm	
				Impinger	DGM In	DGM Out	Vacuum (in Hg)	Impinger	DGM In	DGM Out	Vacuum (in Hg)				
3	0	T	0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	10		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	20		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	30		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	40		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	50		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000
	60		0.1	51	51	5	0.000	5	0.000	5	0.000	5	0.000	5	0.000

Run	Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Time				Initial Leak Check				Final Leak Check			
				Temperature (°F)				in Hg		cfm		in Hg		cfm	
				Impinger	DGM In	DGM Out	Vacuum (in Hg)	Impinger	DGM In	DGM Out	Vacuum (in Hg)				
	0														
	10														
	20														
	30														
	40														
	50														
	60														

## Non-Isokinetic Source Sampling Data Sheet

Project			Source	
Id	Client	Facility	Id	Location
COV	sterilizer	OX		Inlet

Dry Gas Meter			Barometric Pressure (in Hg)	Data	Operators
Id	Δ H @	Y			
V2060			30.52	1-7-19	EB/LS

Run	Time		Initial Leak Check		Final Leak Check	
			in Hg	cfm	in Hg	cfm
1	850-950		✓5	0.000	4	0.000
Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F)		Vacuum (in Hg)	
			Impinger	DGM In	DGM Out	
0	T	0.1	T	44	44	1.5
10		0.1		44	44	1.5
20		0.1		45	45	1.5
30		0.1		45	45	1.5
40		0.1		45	45	1.5
50		0.1		45	45	1.5
60		0.1		45	45	1.5
			Initial Weight (g)		Final Weight (g)	
			—		—	

Run	Time		Initial Leak Check		Final Leak Check	
			in Hg	cfm	in Hg	cfm
2	1000-1100		✓6	0.000	5	0.000
Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F)		Vacuum (in Hg)	
			Impinger	DGM In	DGM Out	
0	T	0.1	T	44	44	1.5
10		0.1		46	46	1.5
20		0.1		46	46	1.5
30		0.1		46	46	1.5
40		0.1		47	47	1.5
50		0.1		47	47	1.5
60		0.1		47	47	1.5
			Initial Weight (g)		Final Weight (g)	
			—		—	

Run	Time		Initial Leak Check		Final Leak Check	
			in Hg	cfm	in Hg	cfm
3	1100-1200		✓6	0.000	6	0.000
Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F)		Vacuum (in Hg)	
			Impinger	DGM In	DGM Out	
0	T	0.1	T	47	47	1.5
10		0.1		47	47	1.5
20		0.1		47	47	1.5
30		0.1		47	47	1.5
40		0.1		48	48	1.5
50		0.1		48	48	1.5
60		0.1		48	48	1.5
			Initial Weight (g)		Final Weight (g)	
			—		—	

Run	Time		Initial Leak Check		Final Leak Check	
			in Hg	cfm	in Hg	cfm
Elapsed Time (min)	DGM Volume (liters)	Ball Flow Meter Setting	Temperature (°F)		Vacuum (in Hg)	
			Impinger	DGM In	DGM Out	
0						
10						
20						
30						
40						
50						
60						
			Initial Weight (g)		Final Weight (g)	

---

# **APPENDIX B**

## **EPA Method 18 Data**

## Method 18 Initial Calibration

20-Dec-17

Covidien

## Standards

	Low	Mid	High
Cylinder ID		EA0011733	EA0077506
Expiration Date		5/21/2017	5/21/2017
EO (ppm)	0.0	5.00	10.0

## High

Compound	Conc	Injection									Average	
		15			16			17				
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc
EO	10.00	23.32	9.71	1.50%	24.67	10.27	-4.19%	23.04	9.59	2.69%	23.68	9.86

## Mid

Compound	Conc	Injection									Average	
		21			22			23				
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc
EO	5.00	12.02	5.01	5.35%	12.82	5.34	-0.95%	13.26	5.23	-4.40%	12.70	5.19

## Method 18 Pre and Post Test Calibration

8-Jan-19

Covidien

## Standards

	Low	Mid	High
Cylinder ID		CC126627	
Expiration Date		3/23/2019	
EO (ppm)		5.40	

## Mid Pre Cal

Compound	Conc	Injection									Average		Accuracy
		24			25			26					
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	
EO	5.40	13.1552	5.478	0.3%	13.2136	5.5023	-0.2%	13.1998	5.4966	-0.1%	13.19	5.49	1.71

## Mid Post Cal

Compound	Conc	Injection									Average		Accuracy	Drift
		51			52			53						
		Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc	% Dev	Area	Conc		
EO	5.40	13.0378	5.4291	0.7%	13.0357	5.4282	0.7%	13.3172	5.5454	-1.4%	13.13	5.47	1.25	-0.45%

THE LINDE GROUP

*Linde*

SHIPPED TO: Covidien  
195 McDermott Rd.  
North Haven, CT 06473

PAGE: 1 of 1

## CERTIFICATE OF ANALYSIS

Sales#: 116180708  
Production#: 3136280  
Certification Date: Mar-23-2018  
P.O.#: Recert  
Blend Type: CERTIFIED  
Material#: 14004551  
Traceability: NIST by weight  
Expiration Date: Mar-23-2019  
Do NOT use under: 150 psig

Cylinder Size: 152 (8" X 47.5")  
Cylinder #: CC-126627  
Cylinder Pressure: 1200 psig  
Cylinder Valve: CGA 350 / Steel  
Cylinder Volume: 29.5 Liter  
Cylinder Material: Aluminum  
Gas Volume: 2400 Liters  
Blend Tolerance: 5% Relative  
Analytical Accuracy: 2% Relative

COMPONENT	CAS NUMBER	REQUESTED CONC	CERTIFIED CONC
Ethylene Oxide	75-21-8	5.28 ppm	5.40 ppm
Nitrogen	7727-37-9	Balance	Balance

ANALYST:

*Justin Kutz*  
Justin Kutz

DATE: Mar-23-2018

## Oxidizer Outlet Method 18 Summary

8-Jan-19

Covidien

## Outlet 1

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	28	29	30	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.98	<0.20

## Outlet 2

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	31	32	33	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.98	<0.20

## Outlet 3

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	34	35	36	Average					
EO	<0.20	<0.20	<0.20	<0.20	0.0%	0.0%	0.0%	0.98	<0.20

## Oxidizer Inlet Method 18 Summary

8-Jan-19

Covidien

## Inlet 1

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	38	39	40	Average					
EO	46.2559	46.2647	45.4506	45.9904	-0.6%	-0.6%	1.2%	0.98	47.02

## Inlet 2

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	41	42	43	Average					
EO	36.0763	34.7863	35.8489	35.5705	-1.4%	2.2%	-0.8%	0.98	36.36

## Inlet 3

Compound	Concentration (ppm)				Deviation			Recovery	Corrected (ppm)
	48	49	50	Average					
EO	26.9527	27.5449	27.7368	27.4115	1.7%	-0.5%	-1.2%	0.98	28.02

## Oxidizer Outlet Method 18 Recovery Study Summary

8-Jan-19

EPA Method 18

Covidien

## Recovery Summary

Compound	Sample ID	Sample Volume (ml)	(u) Un-Spiked Sample Response (ppm)	Sample Mass	Standard Volume (ml)	Standard Conc (ppm)	Standard Mass	Spiked Bag Total Conc (ppm)	(s) Theoretical Spike Conc (ppm)	(t) Spiked Sample Response (ppm)	(t-u)/s Recovery (%)
EO	1	2000	0.0	0	2000	9.3	18600	4.65	4.65	4.55	98%

## Spiked Sample Analysis

Compound	Concentration (ppm)				Deviation		
	54	55	56	average (t)			
EO	4.3505	4.6068	4.6883	4.5485	4.4%	-1.3%	-3.1%



Component	Retention	Area	Height	External	Units
ethylene oxide	2.306	13.1552	2.997	5.4780	ppm
		13.1552		5.4780	



Component	Retention	Area	Height	External	Units
ethylene oxide	2.306	13.2136	2.993	5.5023	ppm
		13.2136		5.5023	



Component	Retention	Area	Height	External	Units
ethylene oxide	2.306	13.1998	3.004	5.4966	ppm
		13.1998		5.4966	



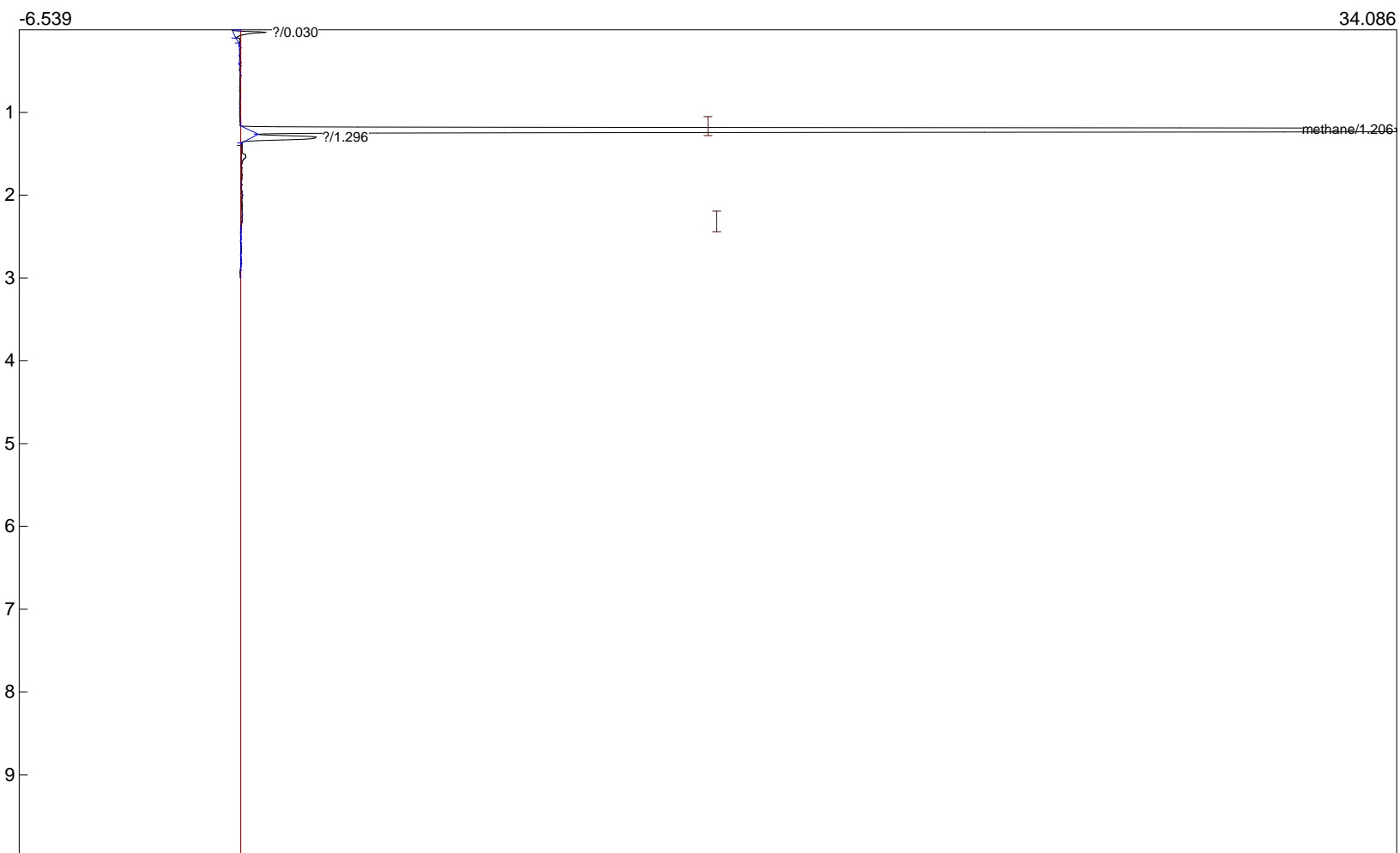
Component	Retention	Area	Height	External	Units
methane	1.206	159.7646	52.915	0.0000	
		159.7646		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.210	159.6233	52.873	0.0000	
		159.6233		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.213	159.6107	52.813	0.0000	
		159.6107		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.206	165.8194	54.708	0.0000	
		165.8194		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.213	165.1702	54.477	0.0000	
		165.1702		0.0000	



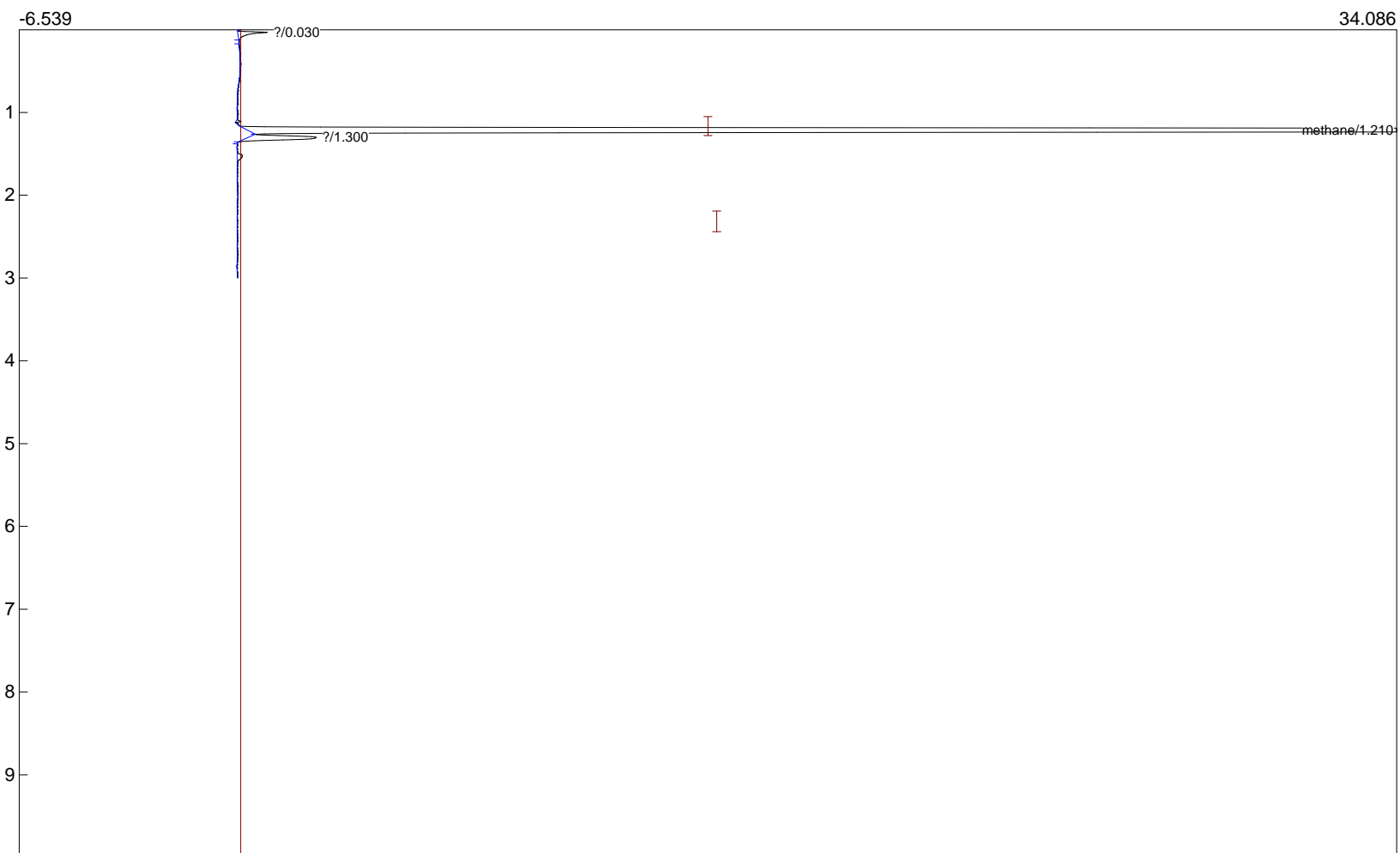
Component	Retention	Area	Height	External	Units
methane	1.210	164.8386	54.538	0.0000	
		164.8386		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.210	173.7789	57.534	0.0000	
		173.7789		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.213	173.7318	57.524	0.0000	
		173.7318		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.210	173.4532	57.699	0.0000	
		173.4532		0.0000	



Component	Retention	Area	Height	External	Units
methane	1.206	11.6662	3.830	0.0000	
ethylene oxide	2.306	11.1082	2.544	46.2559	ppm
		22.7744		46.2559	



Component	Retention	Area	Height	External	Units
methane	1.203	11.9188	3.863	0.0000	
ethylene oxide	2.303	11.1103	2.516	46.2647	ppm
		23.0291		46.2647	



Component	Retention	Area	Height	External	Units
methane	1.203	11.7562	3.843	0.0000	
ethylene oxide	2.300	10.9148	2.496	45.4506	ppm
		22.6710		45.4506	



Component	Retention	Area	Height	External	Units
methane	1.206	11.5946	3.799	0.0000	
ethylene oxide	2.316	8.6636	1.928	36.0763	ppm
		20.2582		36.0763	



Component	Retention	Area	Height	External	Units
methane	1.206	11.5222	3.786	0.0000	
ethylene oxide	2.303	8.3538	1.912	34.7863	ppm
		19.8760		34.7863	



Component	Retention	Area	Height	External	Units
methane	1.203	11.6190	3.795	0.0000	
ethylene oxide	2.303	8.6090	1.912	35.8489	ppm
		20.2280		35.8489	



Component	Retention	Area	Height	External	Units
methane	1.203	11.2980	3.693	0.0000	
ethylene oxide	2.310	6.4726	1.466	26.9527	ppm
		17.7706		26.9527	



Component	Retention	Area	Height	External	Units
methane	1.210	11.2830	3.692	0.0000	
ethylene oxide	2.306	6.6148	1.470	27.5449	ppm
		17.8978		27.5449	



Component	Retention	Area	Height	External	Units
methane	1.206	11.1453	3.675	0.0000	
ethylene oxide	2.296	6.6609	1.469	27.7368	ppm
		17.8062		27.7368	



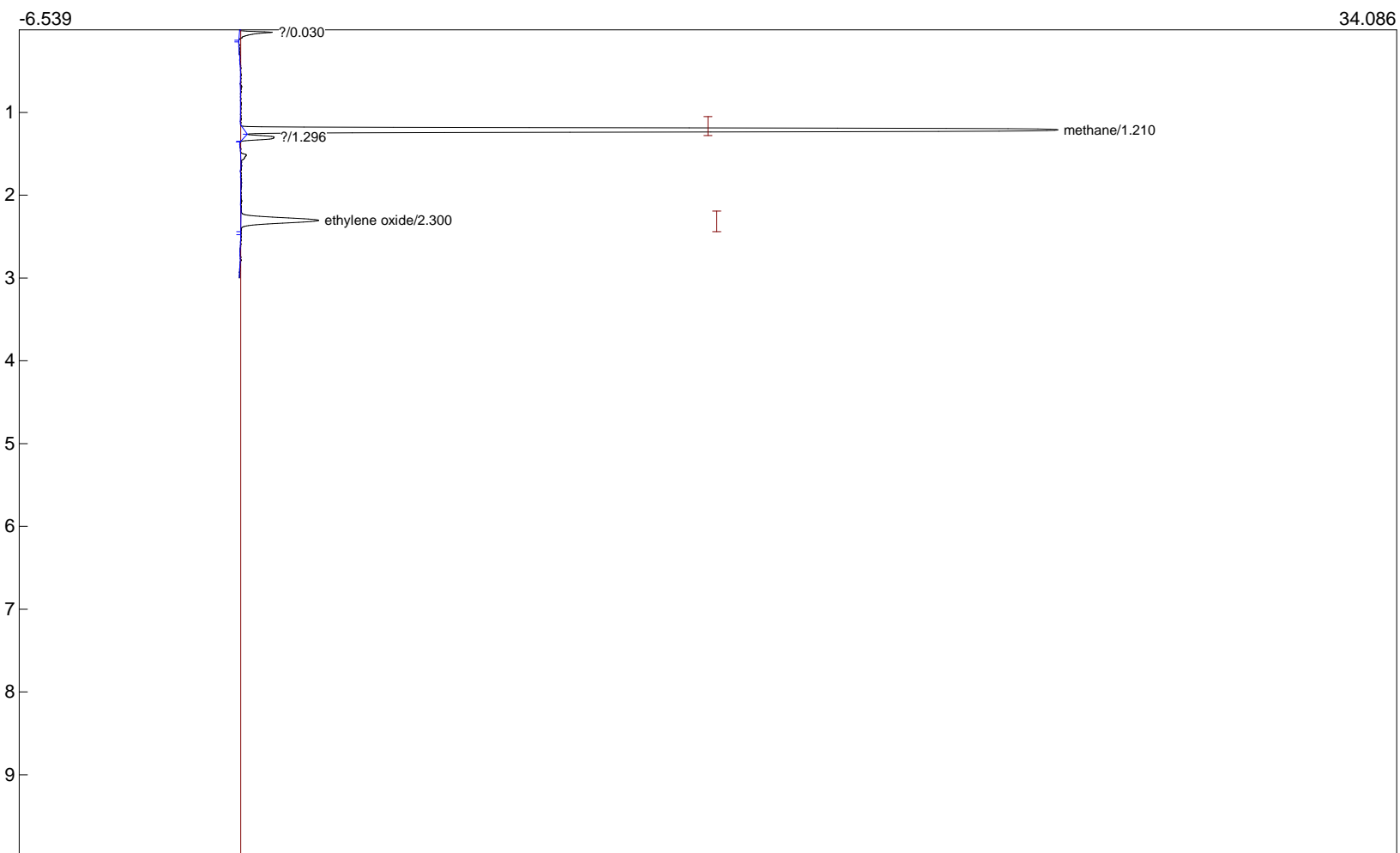
Component	Retention	Area	Height	External	Units
ethylene oxide	2.296	13.0378	2.974	5.4291	ppm
		13.0378		5.4291	



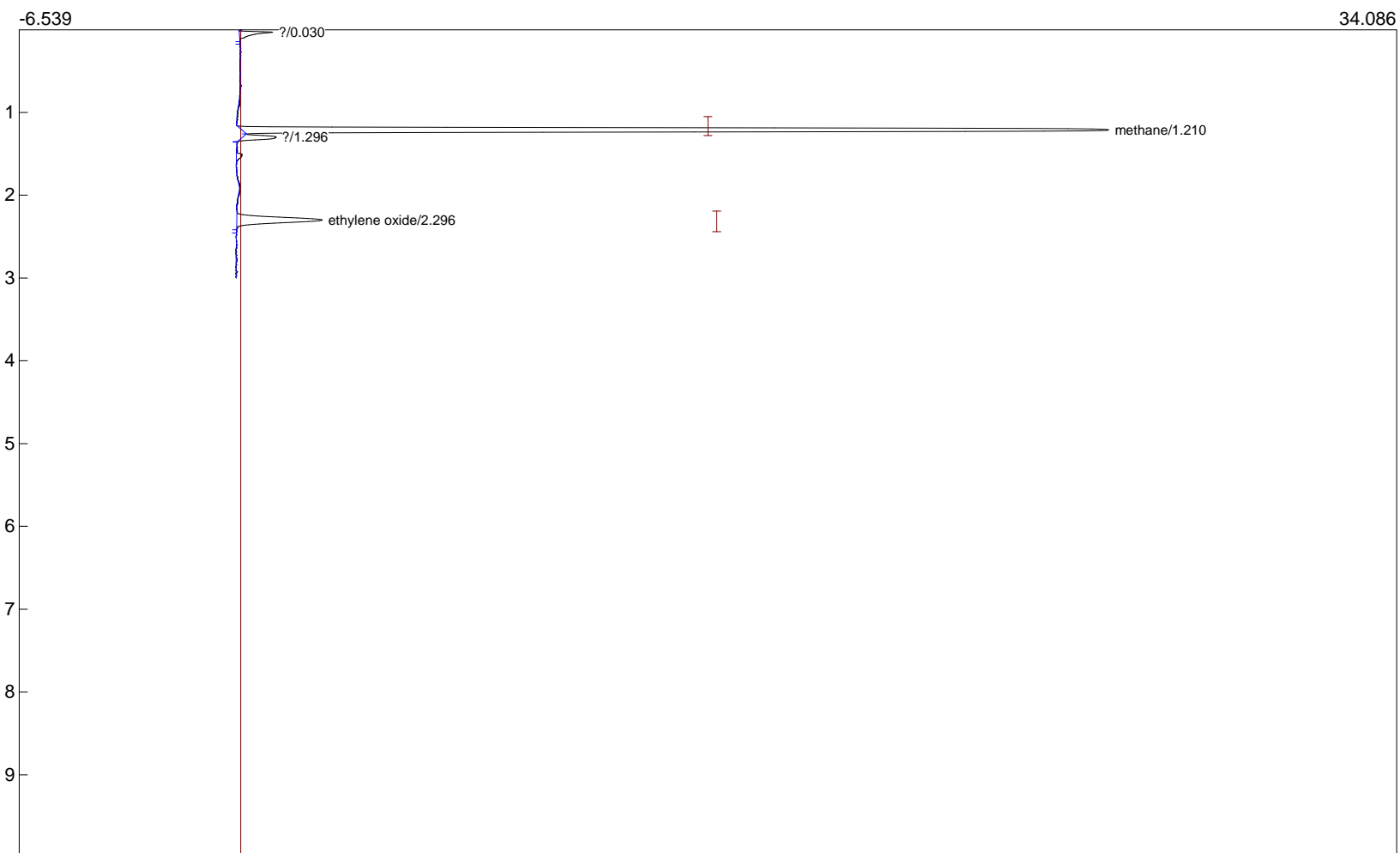
Component	Retention	Area	Height	External	Units
ethylene oxide	2.300	13.0357	2.999	5.4282	ppm
		13.0357		5.4282	



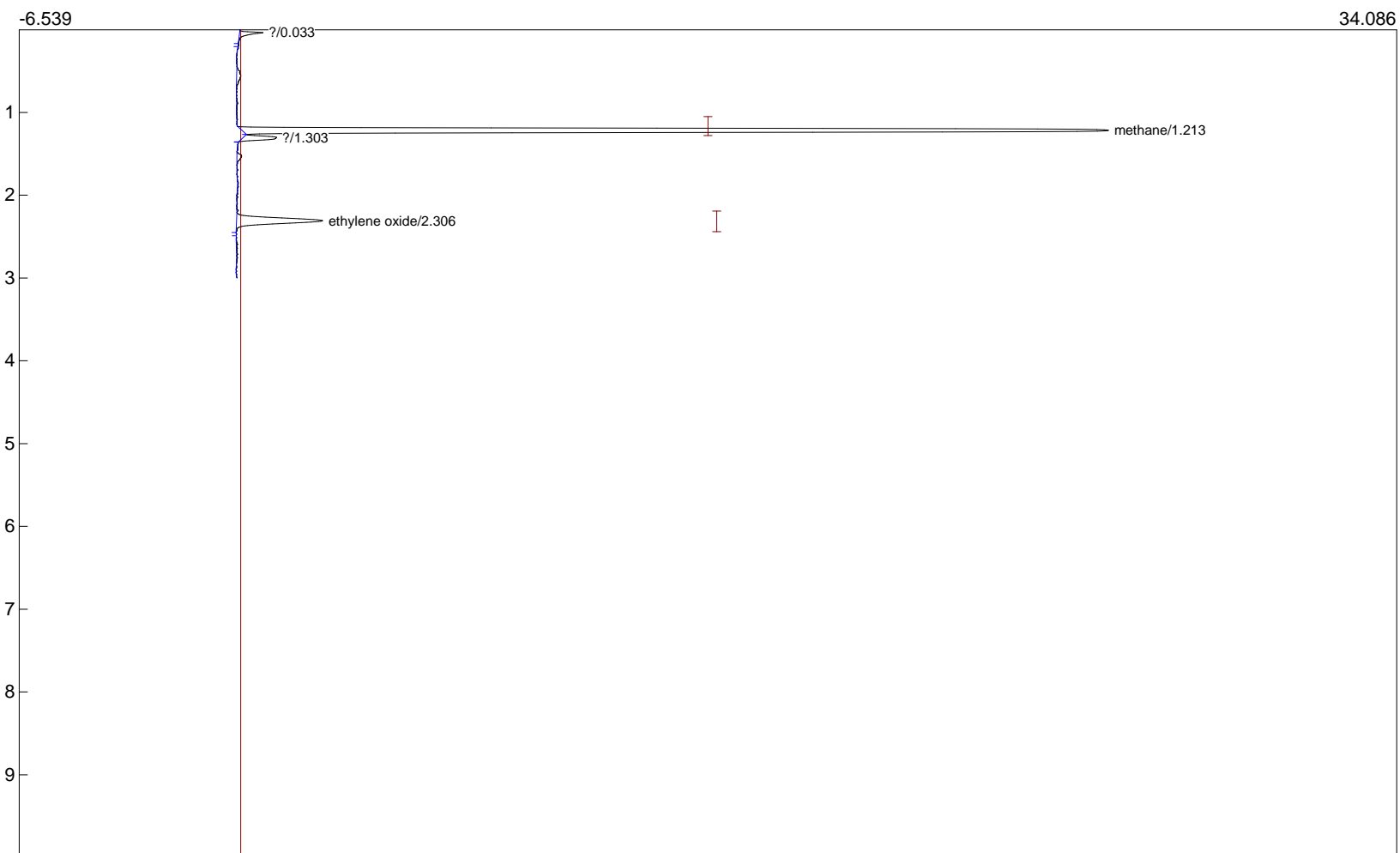
Component	Retention	Area	Height	External	Units
ethylene oxide	2.303	13.3172	2.993	5.5454	ppm
		13.3172		5.5454	



Component	Retention	Area	Height	External	Units
methane	1.210	74.4784	23.998	0.0000	
ethylene oxide	2.300	10.1832	2.295	4.3505	ppm
		84.6616		4.3505	



Component	Retention	Area	Height	External	Units
methane	1.210	79.8269	25.573	0.0000	
ethylene oxide	2.296	11.0630	2.518	4.6068	ppm
		90.8899		4.6068	



Component	Retention	Area	Height	External	Units
methane	1.213	80.2336	25.564	0.0000	
ethylene oxide	2.306	11.2588	2.537	4.6883	ppm
		91.4924		4.6883	

---

# **APPENDIX C**

## **Process Data**

Date	Time	Temp	Average
1/7/2019	8:50:00	158.6177	
1/7/2019	8:50:10	158.5729	
1/7/2019	8:50:20	158.5810	
1/7/2019	8:50:30	158.6030	
1/7/2019	8:50:40	158.6062	
1/7/2019	8:50:50	158.5570	
1/7/2019	8:51:00	158.6264	
1/7/2019	8:51:10	158.5993	
1/7/2019	8:51:20	158.6198	
1/7/2019	8:51:30	158.5555	
1/7/2019	8:51:40	158.5885	
1/7/2019	8:51:50	158.6072	
1/7/2019	8:52:00	158.5987	
1/7/2019	8:52:10	158.5753	
1/7/2019	8:52:20	158.5798	
1/7/2019	8:52:30	158.5837	
1/7/2019	8:52:40	158.5924	
1/7/2019	8:52:50	158.5624	
1/7/2019	8:53:00	158.5741	
1/7/2019	8:53:10	158.6693	
1/7/2019	8:53:20	158.5954	
1/7/2019	8:53:30	158.6023	
1/7/2019	8:53:40	158.5822	
1/7/2019	8:53:50	158.5933	
1/7/2019	8:54:00	158.6047	
1/7/2019	8:54:10	158.6174	
1/7/2019	8:54:20	158.5885	
1/7/2019	8:54:30	158.6144	
1/7/2019	8:54:40	158.5843	
1/7/2019	8:54:50	158.5960	
1/7/2019	8:55:00	158.6195	
1/7/2019	8:55:10	158.5858	
1/7/2019	8:55:20	158.6047	
1/7/2019	8:55:30	158.6099	
1/7/2019	8:55:40	158.5858	
1/7/2019	8:55:50	158.5753	
1/7/2019	8:56:00	158.5504	
1/7/2019	8:56:10	158.5621	
1/7/2019	8:56:20	158.5275	
1/7/2019	8:56:30	158.4672	
1/7/2019	8:56:40	158.5699	
1/7/2019	8:56:50	158.4798	
1/7/2019	8:57:00	158.5452	
1/7/2019	8:57:10	158.5741	
1/7/2019	8:57:20	158.5449	
1/7/2019	8:57:30	158.5122	

1/7/2019	8:57:40	158.5951
1/7/2019	8:57:50	158.5843
1/7/2019	8:58:00	158.5519
1/7/2019	8:58:10	158.5254
1/7/2019	8:58:20	158.4852
1/7/2019	8:58:30	158.5425
1/7/2019	8:58:40	158.5678
1/7/2019	8:58:50	158.4972
1/7/2019	8:59:00	158.5294
1/7/2019	8:59:10	158.5215
1/7/2019	8:59:20	158.5350
1/7/2019	8:59:30	158.5203
1/7/2019	8:59:40	158.5267
1/7/2019	8:59:50	158.4224
1/7/2019	9:00:00	158.4776
1/7/2019	9:00:10	158.5390
1/7/2019	9:00:20	158.5080
1/7/2019	9:00:30	158.4915
1/7/2019	9:00:40	158.5495
1/7/2019	9:00:50	158.5074
1/7/2019	9:01:00	158.5267
1/7/2019	9:01:10	158.5170
1/7/2019	9:01:20	158.5362
1/7/2019	9:01:30	158.5224
1/7/2019	9:01:40	158.5362
1/7/2019	9:01:50	158.5368
1/7/2019	9:02:00	158.5594
1/7/2019	9:02:10	158.4828
1/7/2019	9:02:20	158.4900
1/7/2019	9:02:30	158.5630
1/7/2019	9:02:40	158.5317
1/7/2019	9:02:50	158.5329
1/7/2019	9:03:00	158.5050
1/7/2019	9:03:10	158.4756
1/7/2019	9:03:20	158.4927
1/7/2019	9:03:30	158.5218
1/7/2019	9:03:40	158.5408
1/7/2019	9:03:50	158.5552
1/7/2019	9:04:00	158.5356
1/7/2019	9:04:10	158.5501
1/7/2019	9:04:20	158.4738
1/7/2019	9:04:30	158.5672
1/7/2019	9:04:40	158.5753
1/7/2019	9:04:50	158.5660
1/7/2019	9:05:00	158.5774
1/7/2019	9:05:10	158.6225
1/7/2019	9:05:20	158.6062

1/7/2019	9:05:30	158.6141
1/7/2019	9:05:40	158.5522
1/7/2019	9:05:50	158.6107
1/7/2019	9:06:00	158.5449
1/7/2019	9:06:10	158.5420
1/7/2019	9:06:20	158.5479
1/7/2019	9:06:30	158.5170
1/7/2019	9:06:40	158.5308
1/7/2019	9:06:50	158.5218
1/7/2019	9:07:00	158.5350
1/7/2019	9:07:10	158.5321
1/7/2019	9:07:20	158.5086
1/7/2019	9:07:30	158.4678
1/7/2019	9:07:40	158.4425
1/7/2019	9:07:50	158.4209
1/7/2019	9:08:00	158.4179
1/7/2019	9:08:10	158.4266
1/7/2019	9:08:20	158.3638
1/7/2019	9:08:30	158.3932
1/7/2019	9:08:40	158.4104
1/7/2019	9:08:50	158.4272
1/7/2019	9:09:00	158.3860
1/7/2019	9:09:10	158.4070
1/7/2019	9:09:20	158.4188
1/7/2019	9:09:30	158.3470
1/7/2019	9:09:40	158.3509
1/7/2019	9:09:50	158.3512
1/7/2019	9:10:00	158.2878
1/7/2019	9:10:10	158.3094
1/7/2019	9:10:20	158.3443
1/7/2019	9:10:30	158.3674
1/7/2019	9:10:40	158.3575
1/7/2019	9:10:50	158.3611
1/7/2019	9:11:00	158.3214
1/7/2019	9:11:10	158.2334
1/7/2019	9:11:20	158.2454
1/7/2019	9:11:30	158.2640
1/7/2019	9:11:40	158.2893
1/7/2019	9:11:50	158.2529
1/7/2019	9:12:00	158.2352
1/7/2019	9:12:10	158.2704
1/7/2019	9:12:20	158.2977
1/7/2019	9:12:30	158.3253
1/7/2019	9:12:40	158.2496
1/7/2019	9:12:50	158.2725
1/7/2019	9:13:00	158.2665
1/7/2019	9:13:10	158.2598

1/7/2019	9:13:20	158.2112
1/7/2019	9:13:30	158.2373
1/7/2019	9:13:40	158.1832
1/7/2019	9:13:50	158.2148
1/7/2019	9:14:00	158.2277
1/7/2019	9:14:10	158.2079
1/7/2019	9:14:20	158.2682
1/7/2019	9:14:30	158.2433
1/7/2019	9:14:40	158.2022
1/7/2019	9:14:50	158.1652
1/7/2019	9:15:00	158.2373
1/7/2019	9:15:10	158.1931
1/7/2019	9:15:20	158.2079
1/7/2019	9:15:30	158.2226
1/7/2019	9:15:40	158.1922
1/7/2019	9:15:50	158.1847
1/7/2019	9:16:00	158.2157
1/7/2019	9:16:10	158.2707
1/7/2019	9:16:20	158.2920
1/7/2019	9:16:30	158.2827
1/7/2019	9:16:40	158.2226
1/7/2019	9:16:50	158.2331
1/7/2019	9:17:00	158.2652
1/7/2019	9:17:10	158.2707
1/7/2019	9:17:20	158.2563
1/7/2019	9:17:30	158.2121
1/7/2019	9:17:40	158.2445
1/7/2019	9:17:50	158.2448
1/7/2019	9:18:00	158.2578
1/7/2019	9:18:10	158.2995
1/7/2019	9:18:20	158.3049
1/7/2019	9:18:30	158.3322
1/7/2019	9:18:40	158.3007
1/7/2019	9:18:50	158.3491
1/7/2019	9:19:00	158.3217
1/7/2019	9:19:10	158.2869
1/7/2019	9:19:20	158.2932
1/7/2019	9:19:30	158.3304
1/7/2019	9:19:40	158.2728
1/7/2019	9:19:50	158.2763
1/7/2019	9:20:00	158.2466
1/7/2019	9:20:10	158.2947
1/7/2019	9:20:20	158.3016
1/7/2019	9:20:30	158.3016
1/7/2019	9:20:40	158.2755
1/7/2019	9:20:50	158.2836
1/7/2019	9:21:00	158.3058

1/7/2019	9:21:10	158.2953
1/7/2019	9:21:20	158.2971
1/7/2019	9:21:30	158.2574
1/7/2019	9:21:40	158.3133
1/7/2019	9:21:50	158.2731
1/7/2019	9:22:00	158.2547
1/7/2019	9:22:10	158.2385
1/7/2019	9:22:20	158.2355
1/7/2019	9:22:30	158.2334
1/7/2019	9:22:40	158.2565
1/7/2019	9:22:50	158.2370
1/7/2019	9:23:00	158.2079
1/7/2019	9:23:10	158.1958
1/7/2019	9:23:20	158.2310
1/7/2019	9:23:30	158.2652
1/7/2019	9:23:40	158.2223
1/7/2019	9:23:50	158.2187
1/7/2019	9:24:00	158.1466
1/7/2019	9:24:10	158.1057
1/7/2019	9:24:20	158.1409
1/7/2019	9:24:30	158.1544
1/7/2019	9:24:40	158.1261
1/7/2019	9:24:50	158.1078
1/7/2019	9:25:00	158.1066
1/7/2019	9:25:10	158.1322
1/7/2019	9:25:20	158.1412
1/7/2019	9:25:30	158.1316
1/7/2019	9:25:40	158.1195
1/7/2019	9:25:50	158.1084
1/7/2019	9:26:00	158.0943
1/7/2019	9:26:10	158.0868
1/7/2019	9:26:20	158.1180
1/7/2019	9:26:30	158.1345
1/7/2019	9:26:40	158.1048
1/7/2019	9:26:50	158.0808
1/7/2019	9:27:00	158.0841
1/7/2019	9:27:10	158.1141
1/7/2019	9:27:20	158.0531
1/7/2019	9:27:30	158.0577
1/7/2019	9:27:40	158.0174
1/7/2019	9:27:50	158.1174
1/7/2019	9:28:00	158.1430
1/7/2019	9:28:10	158.0670
1/7/2019	9:28:20	158.0495
1/7/2019	9:28:30	158.0652
1/7/2019	9:28:40	158.0534
1/7/2019	9:28:50	158.0267

1/7/2019	9:29:00	158.0165
1/7/2019	9:29:10	157.9928
1/7/2019	9:29:20	158.0336
1/7/2019	9:29:30	158.0375
1/7/2019	9:29:40	158.0727
1/7/2019	9:29:50	158.0402
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1/7/2019	10:55:10	157.5412
1/7/2019	10:55:20	157.4796
1/7/2019	10:55:30	157.4832
1/7/2019	10:55:40	157.4919
1/7/2019	10:55:50	157.4468
1/7/2019	10:56:00	157.4652
1/7/2019	10:56:10	157.4382
1/7/2019	10:56:20	157.4625
1/7/2019	10:56:30	157.4138
1/7/2019	10:56:40	157.4414
1/7/2019	10:56:50	157.5000
1/7/2019	10:57:00	157.5012

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1/7/2019	10:57:20	157.5301	
1/7/2019	10:57:30	157.5063	
1/7/2019	10:57:40	157.5169	
1/7/2019	10:57:50	157.5076	
1/7/2019	10:58:00	157.4508	
1/7/2019	10:58:10	157.5427	
1/7/2019	10:58:20	157.4991	
1/7/2019	10:58:30	157.5214	
1/7/2019	10:58:40	157.5754	
1/7/2019	10:58:50	157.5935	
1/7/2019	10:59:00	157.5063	
1/7/2019	10:59:10	157.5130	
1/7/2019	10:59:20	157.5415	
1/7/2019	10:59:30	157.5103	
1/7/2019	10:59:40	157.4724	
1/7/2019	10:59:50	157.4652	
1/7/2019	11:00:00	157.4892	157.61
1/7/2019	11:08:00	157.4628	
1/7/2019	11:08:10	157.3931	
1/7/2019	11:08:20	157.4634	
1/7/2019	11:08:30	157.4571	
1/7/2019	11:08:40	157.3750	
1/7/2019	11:08:50	157.4682	
1/7/2019	11:09:00	157.3934	
1/7/2019	11:09:10	157.4000	
1/7/2019	11:09:20	157.4039	
1/7/2019	11:09:30	157.3678	
1/7/2019	11:09:40	157.3705	
1/7/2019	11:09:50	157.4258	
1/7/2019	11:10:00	157.3952	
1/7/2019	11:10:10	157.3763	
1/7/2019	11:10:20	157.3910	
1/7/2019	11:10:30	157.4012	
1/7/2019	11:10:40	157.3471	
1/7/2019	11:10:50	157.3510	
1/7/2019	11:11:00	157.3841	
1/7/2019	11:11:10	157.3225	
1/7/2019	11:11:20	157.3204	
1/7/2019	11:11:30	157.3805	
1/7/2019	11:11:40	157.2783	
1/7/2019	11:11:50	157.3777	
1/7/2019	11:12:00	157.3723	
1/7/2019	11:12:10	157.2837	
1/7/2019	11:12:20	157.4015	
1/7/2019	11:12:30	157.3252	
1/7/2019	11:12:40	157.3348	

1/7/2019	11:12:50	157.3597
1/7/2019	11:13:00	157.3038
1/7/2019	11:13:10	157.3198
1/7/2019	11:13:20	157.3090
1/7/2019	11:13:30	157.3135
1/7/2019	11:13:40	157.3297
1/7/2019	11:13:50	157.3717
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1/7/2019	11:14:10	157.2759
1/7/2019	11:14:20	157.2858
1/7/2019	11:14:30	157.2582
1/7/2019	11:14:40	157.3255
1/7/2019	11:14:50	157.2831
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1/7/2019	11:15:20	157.2447
1/7/2019	11:15:30	157.2981
1/7/2019	11:15:40	157.2639
1/7/2019	11:15:50	157.2711
1/7/2019	11:16:00	157.2804
1/7/2019	11:16:10	157.3690
1/7/2019	11:16:20	157.2585
1/7/2019	11:16:30	157.3354
1/7/2019	11:16:40	157.3736
1/7/2019	11:16:50	157.3225
1/7/2019	11:17:00	157.3780
1/7/2019	11:17:10	157.3108
1/7/2019	11:17:20	157.3624
1/7/2019	11:17:30	157.2768
1/7/2019	11:17:40	157.2615
1/7/2019	11:17:50	157.3204
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1/7/2019	11:18:20	157.2933
1/7/2019	11:18:30	157.4288
1/7/2019	11:18:40	157.3074
1/7/2019	11:18:50	157.3808
1/7/2019	11:19:00	157.3255
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1/7/2019	11:19:20	157.3559
1/7/2019	11:19:30	157.2891
1/7/2019	11:19:40	157.3736
1/7/2019	11:19:50	157.3282
1/7/2019	11:20:00	157.3279
1/7/2019	11:20:10	157.3114
1/7/2019	11:20:20	157.2819
1/7/2019	11:20:30	157.2816

1/7/2019	11:20:40	157.2621
1/7/2019	11:20:50	157.2642
1/7/2019	11:21:00	157.3339
1/7/2019	11:21:10	157.2951
1/7/2019	11:21:20	157.2095
1/7/2019	11:21:30	157.2417
1/7/2019	11:21:40	157.2678
1/7/2019	11:21:50	157.2585
1/7/2019	11:22:00	157.2399
1/7/2019	11:22:10	157.1888
1/7/2019	11:22:20	157.1674
1/7/2019	11:22:30	157.1957
1/7/2019	11:22:40	157.1876
1/7/2019	11:22:50	157.1566
1/7/2019	11:23:00	157.1197
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1/7/2019	11:23:20	157.1993
1/7/2019	11:23:30	157.1882
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1/7/2019	11:23:50	157.1879
1/7/2019	11:24:00	157.2756
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1/7/2019	11:24:20	157.2257
1/7/2019	11:24:30	157.1963
1/7/2019	11:24:40	157.2143
1/7/2019	11:24:50	157.2179
1/7/2019	11:25:00	157.1825
1/7/2019	11:25:10	157.1708
1/7/2019	11:25:20	157.2086
1/7/2019	11:25:30	157.1609
1/7/2019	11:25:40	157.2227
1/7/2019	11:25:50	157.2167
1/7/2019	11:26:00	157.1927
1/7/2019	11:26:10	157.1891
1/7/2019	11:26:20	157.2384
1/7/2019	11:26:30	157.2780
1/7/2019	11:26:40	157.2630
1/7/2019	11:26:50	157.2618
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1/7/2019	11:27:20	157.2155
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1/7/2019	11:27:50	157.2170
1/7/2019	11:28:00	157.2483
1/7/2019	11:28:10	157.2380
1/7/2019	11:28:20	157.2362

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1/7/2019	11:29:30	157.2293
1/7/2019	11:29:40	157.2513
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1/7/2019	11:30:10	157.2113
1/7/2019	11:30:20	157.2447
1/7/2019	11:30:30	157.1939
1/7/2019	11:30:40	157.2173
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1/7/2019	11:31:10	157.1650
1/7/2019	11:31:20	157.1650
1/7/2019	11:31:30	157.1948
1/7/2019	11:31:40	157.2167
1/7/2019	11:31:50	157.0987
1/7/2019	11:32:00	157.0692
1/7/2019	11:32:10	157.1590
1/7/2019	11:32:20	157.1137
1/7/2019	11:32:30	157.1131
1/7/2019	11:32:40	157.1044
1/7/2019	11:32:50	157.1386
1/7/2019	11:33:00	157.0830
1/7/2019	11:33:10	157.0587
1/7/2019	11:33:20	157.1413
1/7/2019	11:33:30	157.0785
1/7/2019	11:33:40	157.0172
1/7/2019	11:33:50	157.0554
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1/7/2019	11:34:30	157.0271
1/7/2019	11:34:40	157.0692
1/7/2019	11:34:50	157.0358
1/7/2019	11:35:00	157.0875
1/7/2019	11:35:10	157.0467
1/7/2019	11:35:20	157.0458
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1/7/2019	11:36:50	157.0305
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1/7/2019	11:38:40	157.0953
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1/7/2019	11:41:30	157.1203
1/7/2019	11:41:40	157.1317
1/7/2019	11:41:50	157.1473
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1/7/2019	11:43:20	157.1407
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1/7/2019	11:43:40	157.1050
1/7/2019	11:43:50	157.1091
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1/7/2019	11:44:20	157.1311
1/7/2019	11:44:30	157.1663
1/7/2019	11:44:40	157.1494
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1/7/2019	11:45:20	157.1524
1/7/2019	11:45:30	157.1464
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1/7/2019	11:46:40	157.1705
1/7/2019	11:46:50	157.1554
1/7/2019	11:47:00	157.1113
1/7/2019	11:47:10	157.1245
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1/7/2019	11:47:30	157.1215
1/7/2019	11:47:40	157.1488
1/7/2019	11:47:50	157.1720
1/7/2019	11:48:00	157.1091
1/7/2019	11:48:10	157.1152
1/7/2019	11:48:20	157.1981
1/7/2019	11:48:30	157.1626
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1/7/2019	11:48:50	157.2318
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1/7/2019	11:49:50	157.2498
1/7/2019	11:50:00	157.3321
1/7/2019	11:50:10	157.2843
1/7/2019	11:50:20	157.2483
1/7/2019	11:50:30	157.2353
1/7/2019	11:50:40	157.3132
1/7/2019	11:50:50	157.2873
1/7/2019	11:51:00	157.2978
1/7/2019	11:51:10	157.2957
1/7/2019	11:51:20	157.3594
1/7/2019	11:51:30	157.3613
1/7/2019	11:51:40	157.3504
1/7/2019	11:51:50	157.3525

1/7/2019	11:52:00	157.3501
1/7/2019	11:52:10	157.3988
1/7/2019	11:52:20	157.4108
1/7/2019	11:52:30	157.3654
1/7/2019	11:52:40	157.4105
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1/7/2019	11:53:50	157.5154
1/7/2019	11:54:00	157.4430
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1/7/2019	11:54:20	157.4721
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1/7/2019	11:54:50	157.4676
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1/7/2019	11:55:10	157.4477
1/7/2019	11:55:20	157.4664
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1/7/2019	11:55:40	157.4784
1/7/2019	11:55:50	157.5202
1/7/2019	11:56:00	157.5214
1/7/2019	11:56:10	157.5349
1/7/2019	11:56:20	157.5186
1/7/2019	11:56:30	157.5015
1/7/2019	11:56:40	157.4445
1/7/2019	11:56:50	157.5376
1/7/2019	11:57:00	157.5328
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1/7/2019	11:57:20	157.5580
1/7/2019	11:57:30	157.4607
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1/7/2019	11:58:10	157.5223
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1/7/2019	11:58:30	157.5217
1/7/2019	11:58:40	157.4850
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1/7/2019	11:59:00	157.4832
1/7/2019	11:59:10	157.4502
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1/7/2019	11:59:30	157.3768
1/7/2019	11:59:40	157.4315

1/7/2019	11:59:50	157.4826
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1/7/2019	12:00:10	157.3952
1/7/2019	12:00:20	157.4192
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1/7/2019	12:00:40	157.4514
1/7/2019	12:00:50	157.3739
1/7/2019	12:01:00	157.4520
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1/7/2019	12:01:20	157.4150
1/7/2019	12:01:30	157.3654
1/7/2019	12:01:40	157.3360
1/7/2019	12:01:50	157.3309
1/7/2019	12:02:00	157.2750
1/7/2019	12:02:10	157.3150
1/7/2019	12:02:20	157.3041
1/7/2019	12:02:30	157.2966
1/7/2019	12:02:40	157.3201
1/7/2019	12:02:50	157.2414
1/7/2019	12:03:00	157.2504
1/7/2019	12:03:10	157.2426
1/7/2019	12:03:20	157.2356
1/7/2019	12:03:30	157.1900
1/7/2019	12:03:40	157.2321
1/7/2019	12:03:50	157.1485
1/7/2019	12:04:00	157.1410
1/7/2019	12:04:10	157.1500
1/7/2019	12:04:20	157.1395
1/7/2019	12:04:30	157.1236
1/7/2019	12:04:40	157.1404
1/7/2019	12:04:50	157.1362
1/7/2019	12:05:00	157.1918
1/7/2019	12:05:10	157.1810
1/7/2019	12:05:20	157.1419
1/7/2019	12:05:30	157.2221
1/7/2019	12:05:40	157.1290
1/7/2019	12:05:50	157.1028
1/7/2019	12:06:00	157.0830
1/7/2019	12:06:10	157.1305
1/7/2019	12:06:20	157.0716
1/7/2019	12:06:30	157.0596
1/7/2019	12:06:40	157.1221
1/7/2019	12:06:50	157.0935
1/7/2019	12:07:00	157.0824
1/7/2019	12:07:10	157.0548
1/7/2019	12:07:20	157.0506
1/7/2019	12:07:30	157.0509

1/7/2019	12:07:40	156.9743	
1/7/2019	12:07:50	157.0683	
1/7/2019	12:08:00	157.0581	157.25

---

# **Appendix D**

## **Test Method Descriptions**

# EPA Method 1

## Sample and Velocity Traverses for Stationary Sources

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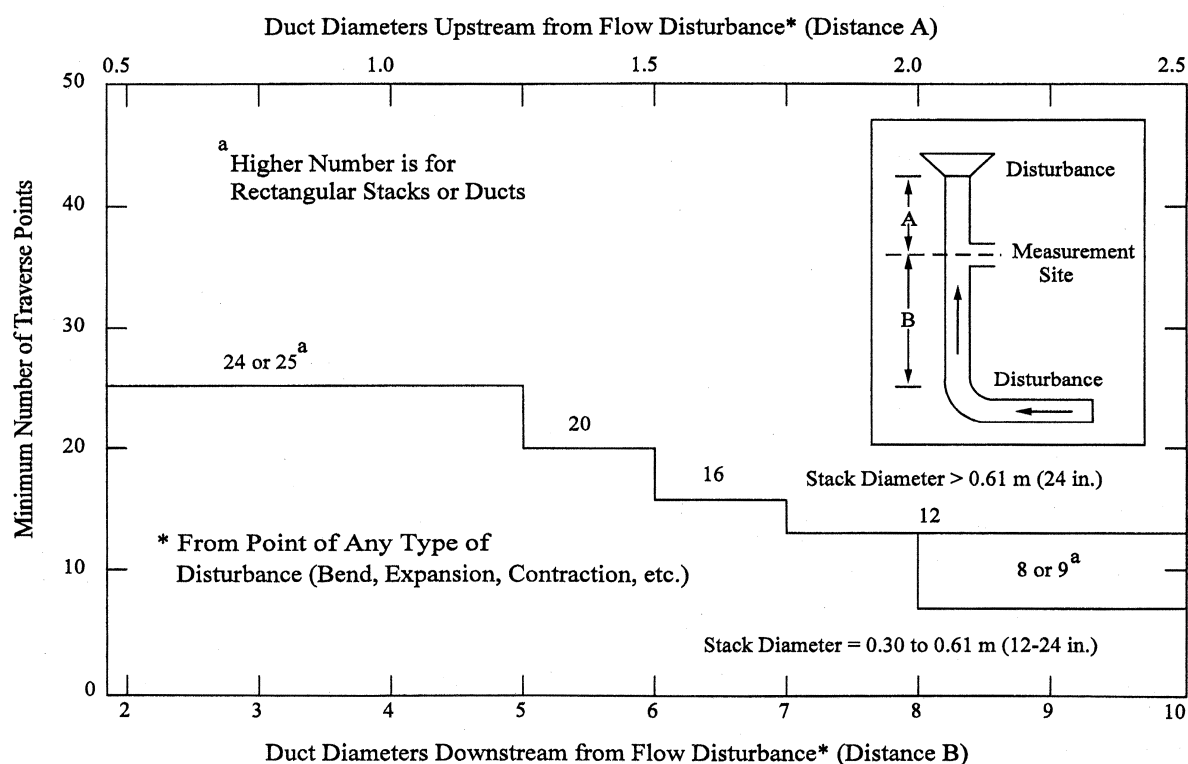
### SUMMARY

A measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. Traverse points are then located within each of these equal areas.

### SITE SELECTION

- Sampling or velocity measurements must be taken at a position at least 2 stack diameters downstream and a half diameter upstream from any flow disturbance.
- The minimum allowed number of traverse points can be used when there is at least 8 stack diameters downstream and 2 stack diameters upstream.
- For particulate traverses refer to table 1 to determine the required number of traverse points
- For velocity traverses refer to table 2 to determine the required number of traverse points
- For circular stacks, locate the traverse points on two perpendicular diameters according to the diameter percentages listed in table 3.
- For rectangular stacks, divide the stack into as many equal areas as traverse points and locate each traverse point in the center of each area.
- Verify the absence of cyclonic flow using a Type S pitot tube and the manometer nulling technique.

**Table 1**  
**Particulate Traverses**



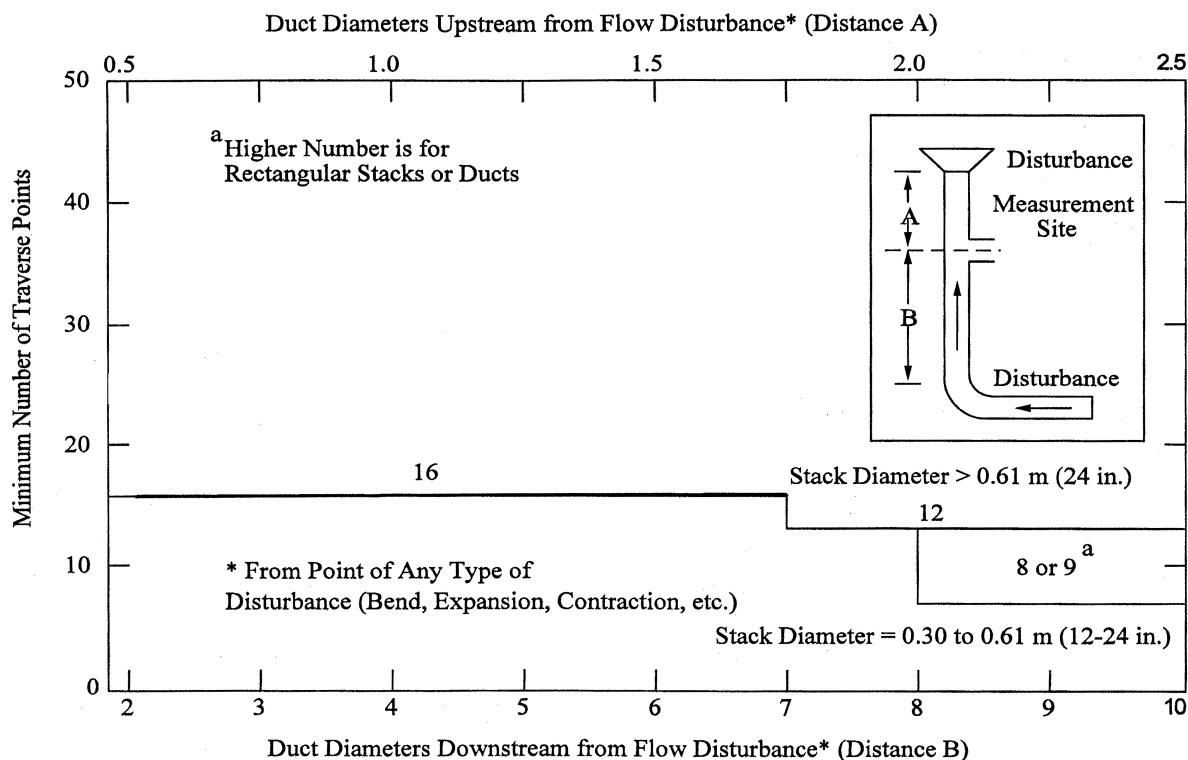
Revised: 01/17/2019

# EPA Method 1

## Sample and Velocity Traverses for Stationary Sources

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**Table 2**  
**Velocity Traverses**



**Table 3**  
**Location of Traverse Points in Circular Stacks**

Traverse Point	Number of Traverse Points on a Diameter				
	4	6	8	10	12
1	6.7	4.4	3.2	2.6	2.1
2	25.0	14.6	10.5	8.2	6.7
3	75.0	29.6	19.4	14.6	11.8
4	93.3	70.4	32.3	22.6	17.7
5		85.4	67.7	34.2	25.0
6		95.6	80.6	65.8	35.6
7			89.5	77.4	64.4
8			96.8	85.4	75.0
9				91.8	82.3
10				97.4	88.2
11					93.3
12					97.9

Revised: 01/17/2019

## EPA Method 2

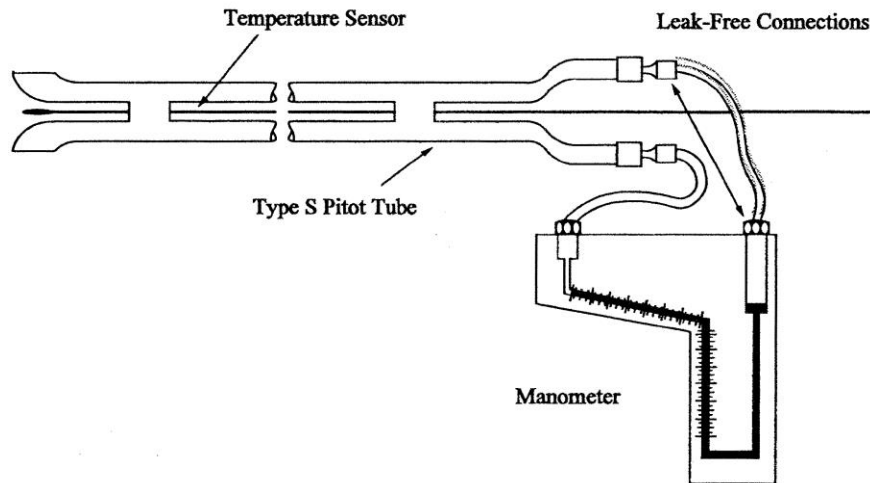
### Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

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#### SUMMARY

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

#### MEASUREMENT EQUIPMENT



- Type S pitot tube constructed of stainless steel or other appropriate metal with a known coefficient.
- Leak free flexible tubing
- Differential pressure gauge such as in inclined manometer with a 10-inch water column with gradations of 0.01 - 0.1 inH<sub>2</sub>O for  $\Delta p$  readings greater than 0.05 inH<sub>2</sub>O.
- Temperature sensor such as a K-Type thermocouple attached to the pitot tube.

#### SAMPLING PROCEDURE

- It is recommended that a pre-test leak check be conducted by blowing into the positive side of the pitot tube until at least 3.0 inH<sub>2</sub>O is registered on the manometer. Block off the opening and observe that the reading remains stable for at least 15 seconds. Follow the same procedure on the negative side of the pitot tube using suction.
- Measure velocity head and temperature and the traverse points determined by EPA Method 1.
- Measure the static pressure in the stack.
- Determine the atmospheric pressure.
- Determine the stack gas dry molecular weight using EPA Method 3 or 3a.
- Determine moisture content using EPA Method 4, wet-bulb/dry-bulb, or saturation.

#### QUALITY ASSURANCE

- Pitot tube calibration by either geometric or wind tunnel measurements.
- Thermocouple calibration using an ice bath and boiling water.
- Pitot tube leak checks conducted before and after each velocity traverse.
- Maintain a properly leveled and zeroed manometer.

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## EPA Method 18

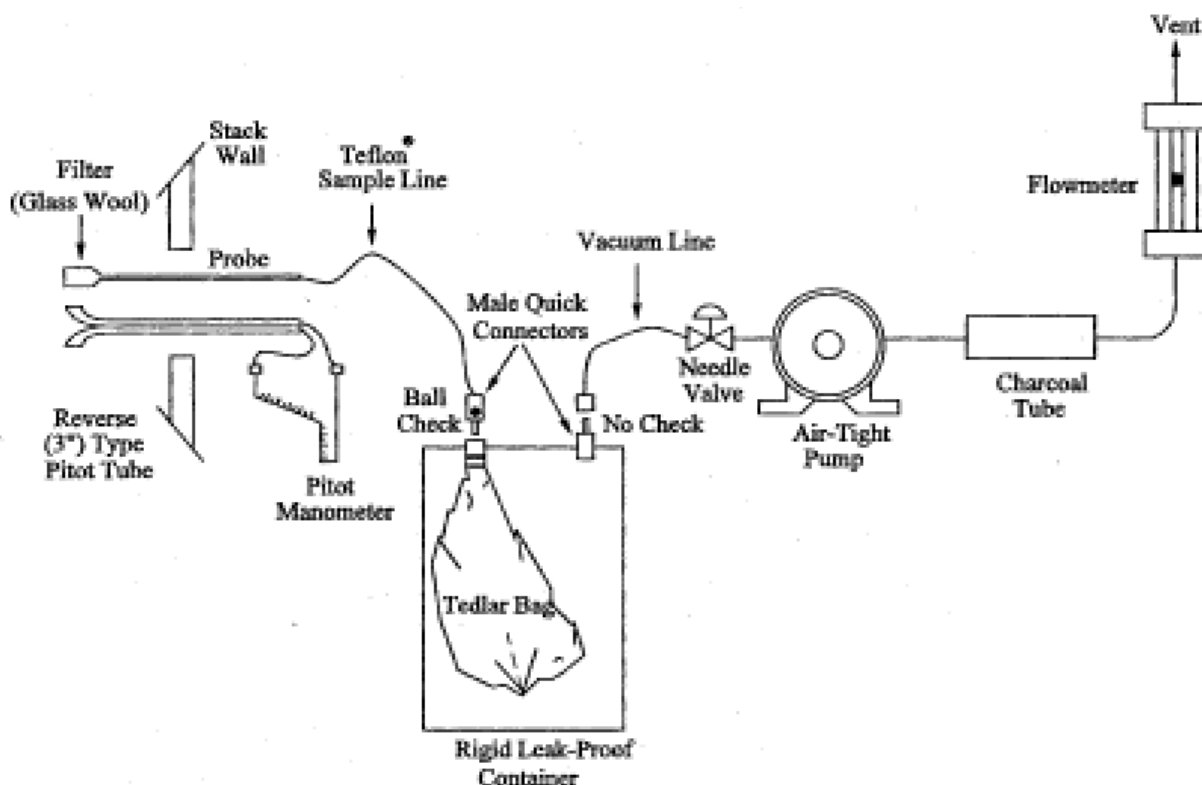
### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

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#### SUMMARY

Sample gas is collected in a Tedlar bag at a constant rate and the bag sample is analyzed by gas chromatography for volatile organic compounds. A sampling train schematic is shown below and photographs are attached.

#### SAMPLING TRAIN



#### Sampling Components:

- Glass or stainless steel probe of sufficient length to reach required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Sample line made of Teflon or other material that does not absorb or alter the sample gas.
- Rigid gas tight container with compression type fittings
- Flexible bags constructed of Tedlar or other inert material
- Gas flow meter or critical orifice flow controller
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.

#### Analytical Components

- SRI Inc. Model 8610C gas chromatograph, laptop computer with Peaksimple software and USB cable
- Restek MXT-1 60 meter steel capillary column (test protocol will specify other column type if required)

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- High purity hydrogen, nitrogen and air
- CGA 350, 580 and 590 gas cylinder regulators with 1/8-inch tubing connectors
- 1,000 cc gas syringe
- Printer (optional as all chromatography files are saved)

## SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- For critical orifice flow controllers, calibrate the sampling rate with a gas flow calibrator.
- Set sampling rate to fill a Tedlar bag approximately 80% full over the test period. A typical sampling rate is 0.16 liters per minute to collect a 9.6 liter sample in a 12 liter bag over a 1-hour period.
- Position the probe at the first sampling point and purge the system for at least two times the response time.
- Record sampling data on a prepared form. Sampling data may include dry gas meter volume, flow meter ball level, temperature, vacuum and pressure.

## ANALYTICAL PROCEDURES

- Set up SRI Model 8610C chromatograph in accordance with manufacturer specifications.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct a 3-level calibration on the gas chromatograph for each target compound using commercially available gas standards. Each gas standard must be analyzed three times and the responses must be within 5% of the mean for each target compound.
- Analyze samples after completing the initial calibration. Samples are also analyzed in triplicate and responses must be within 5% of the mean.
- Periodically analyze zero grade nitrogen or air to demonstrate system is contamination free.
- Prepare a bag recovery spike using one of the sample bags. The recovery spike is prepared using a gas syringe (see attached photograph) and one of the calibration standards. Inject a volume of standard gas into the sample bag to increase the target compound concentration by 40-60%. Analyze the spiked sample in triplicate and calculate recovery using the Method 18 controlled spreadsheet. Sample values are corrected using a spike recovery factor.
- After completing sample analyses, re-analyze the mid-level calibration gas in triplicate. If the average value of each target compound is within 5% of the initial value, the initial calibration can be used to quantify the samples. If the post-test calibration varies by more than 5% of the initial calibration, then the 3-point calibration must be repeated and both pre and post-test calibrations must be used for sample quantification.

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## QUALITY ASSURANCE

### Sampling System:

- Sample flow rate should be  $\pm 2\%$ .
- Leak rate should be 0.00 liters per minute at 5 inches Hg vacuum

### Chromatography Analysis:

- Standards, samples and spikes must be analyzed in triplicate and responses must be within 5% of the mean.
- Spike recovery must be within 70 – 130%.

### Calibration Gas:

- Calibration uncertainty of  $\leq 2\%$  certified value
- Gas used only prior to expiration date

## CALCULATIONS

### Triplicate Injection:

$$\text{Dev} = \frac{(\text{RP}_{\text{avg}} - \text{RP})}{\text{RP}_{\text{avg}}} \times 100$$

RP      Chromatograph response in area units

$\text{RP}_{\text{avg}}$       Average response of three injections

Dev      Deviation from the mean value

### Drift Assessment:

$$D = |\text{SB}_{\text{final}} - \text{SB}_i|$$

D      Drift assessment, percent of calibration span

$\text{SB}_{\text{final}}$       Post-run system response for the mid-level gas

$\text{SB}_i$       Pre-run system response for the mid-level gas

### Spike Recovery Correction:

$$C_{\text{Gas}} = C_{\text{Avg}} \times R$$

$C_{\text{Gas}}$       Average effluent gas concentration adjusted for spike recovery, ppmv

$C_{\text{Avg}}$       Average unadjusted gas concentration for the test run, ppmv

R      Recovery Factor

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### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

#### Recovery Study:

#### EPA Method 18 Section 8.4.2 Recovery Study for Bag Sampling Example Calculation

	Sample ID	Post Analysis Sample Volume (l)	Un-Spiked Sample Response (u) (ppm)	Compound Volume in Sample (ul)	Standard Volume Added to Sample (L)	Standard Conc (ppm)	Compound Volume from Standard (ul)	Spiked Bag Total Conc (ppm)	Theoretical Spike Conc (s) (ppm)	Spiked Sample Response (t) (ppm)	(t-u)/s Recovery (%)
Compound 1	Run 1	6.977	0.0	0.0	0.400	9.4	3.752	0.51	0.51	0.50	98.3%

#### Spiked Sample Analysis

Injection No.	Concentration (ppm)				Deviation		
	1	2	3	average (t)			
Compound 1	0.50	0.50	0.50	0.50	0.0%	0.0%	0.0%

Recovery = (t-u)/s x 100

$$= (0.50-0.00)/0.51 \times 100 = 98.3\%$$

**Bag Sample Volume** meter Y= 0.9828

	Meter Volume (liters)	Pbar	Standard Volume (liters)
Temp (°F)			
60.0	7.055	30.08	7.127

#### Sample Volume Used for Initial Analyses

# of injections	rate (cc/min)	time (min)	Volume (liters)
3	50	1	0.15

#### Detection Limit

Detection limit is determined by analyzing the low standard seven times and applying a standard statistical analysis. An example of the detection limit determination is shown below.

Standard Conc (ppm)	Response (ppm) <sup>1</sup>							Average	Standard Deviation	MDL (ppm) <sup>2</sup>
	1	2	3	4	5	6	7			
1.00	1.181	1.129	1.166	1.171	1.183	1.185	1.182	1.1710	0.020	0.062

1. The low standard is analyzed 7 consecutive times.

2. MDL (ppm) = STDEV x 3.143

STDEV = standard deviation of the response for 7 injections of the low standard

3.143 = Student T-value for n-1 degrees of freedom at a 99% confidence

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#### Mass Emission Rate

Pollutant mass emission rate in pounds per hour (lb/hour) is calculated from the measured concentration and exhaust gas flow rate as follows:

$$ER = \text{ppmw} \times \text{molecular weight} \times \text{scfm} \times 15.58 \times 10^{-8}$$

ER = emission rate (lb/hour)

ppmw = parts per million by volume – wet basis

scfm = standard cubic feet per minute (wet)

#### Mass Basis Destruction Efficiency

Mass basis destruction efficiency is calculated with measured pollutant flow rates at the control device inlet and outlet using the following calculation:

$$\text{Destruction Efficiency (\%)} = (ER_{\text{in}} - ER_{\text{out}}) / ER_{\text{in}} \times 100$$

ER<sub>in</sub> = control device inlet pollutant flow rate (lb/hour)

ER<sub>out</sub> = control device outlet pollutant flow rate (lb/hour)

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Gaseous Organic Compound Emissions by Gas Chromatography  
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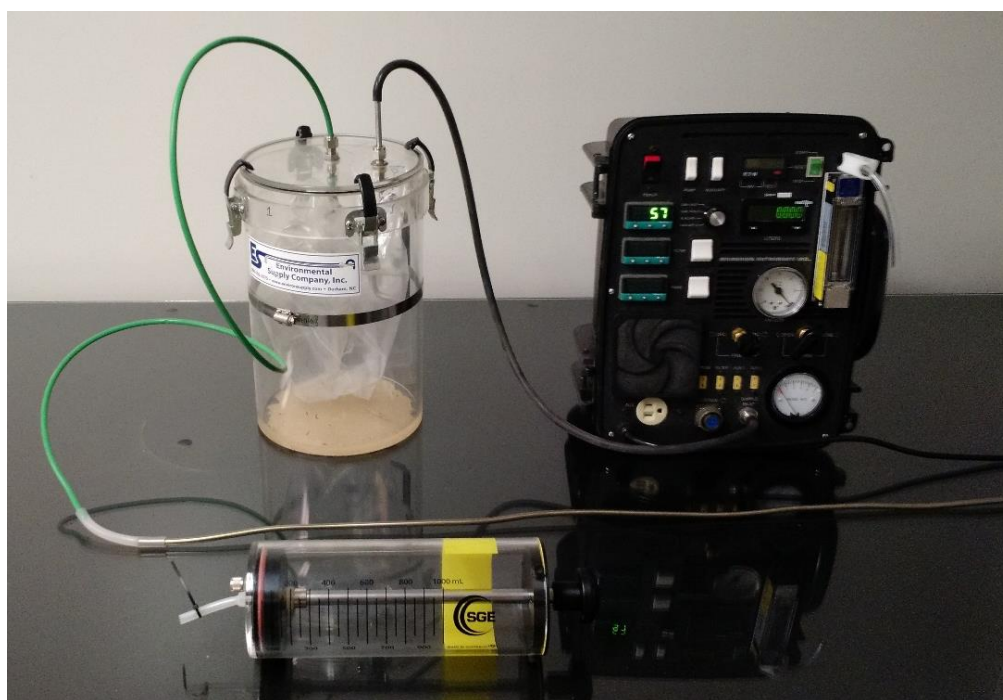
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### COMPONENT IMAGES

SRI, Inc. Model 8610C Gas Chromatograph:



EPA Method 18 Bag Sampling Device and Gas Syringe for Recovery Study:



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